

The Robotic Super-LOTIS Telescope: Results & Future Plans

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Abstract. We provide an overview of the robotic Super-LOTIS (Livermore Optical Transient Imaging System) telescope and present results from gamma-ray burst (GRB) afterglow observations using Super-LOTIS and other Steward Observatory telescopes. The 0.6-m Super-LOTIS telescope is a fully robotic system dedicated to the measurement of prompt and early time optical emission from GRBs. The system began routine operations from its Steward Observatory site atop Kitt Peak in April 2000 and currently operates every clear night. The telescope is instrumented with an optical CCD camera and a four position filter wheel. It is capable of observing Swift Burst Alert Telescope (BAT) error boxes as early or earlier than the Swift UV/Optical Telescope (UVOT). Super-LOTIS complements the UVOT observations by providing early R- and I-band imaging. We also use the suite of Steward Observatory telescopes including the 1.6-m Kuiper, the 2.3-m Bok, the 6.5-m MMT, and the 8.4-m Large Binocular Telescope to perform follow-up optical and near infrared observations of GRB afterglows. These follow-up observations have traditionally required human intervention but we are currently working to automate the 1.6-m Kuiper telescope to minimize its response time.

Keywords: Super-LOTIS, gamma-ray bursts, afterglows

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INTRODUCTION

The Super-LOTIS collaboration aims to obtain two types of data sets that can be used independently or together to provide a more complete understanding of the physics of GRBs. These data sets are: (1) very early optical imaging, and (2) follow-up optical and near infrared imaging, spectroscopy, and polarimetry. The early optical imaging is provided by a fully robotic 0.6-m telescope and the follow-up data comes from larger aperture Steward Observatory telescopes.

Early-time GRB optical counterpart identification is important because it provides information such as: (1) the peak optical flux, useful for planning follow-up observations; (2) the early decay indices, useful in identifying subsequent flaring activity or breaks in the light curve; (3) color, useful in estimating redshift and planning follow-up observations; and (4) variability, useful in understanding continued activity in the central engine or structure in the circumburst medium [e. g. 1]. Perhaps the most scientifically valuable of these is the variability which manifests itself in different forms that are still not

TABLE 1. Super-LOTIS characteristics.

Site:	Steward Observatory, Kitt Peak
Aperture:	0.6-m
Instrument:	Spectral Instruments 800 Series Camera
Detector:	E2V TE Cooled CCD
Format:	2048 × 2048, 13.5 μ m pixels
Pixel Scale:	0.5''/pix
Field-of-View:	17' × 17'
Filters:	V, R, I, H- α
Limiting Magnitude:	R \sim 17.5 (10 s), R \sim 18.5 (60 s)
Slew Speed:	8°/s
Response Time:	< 25 s
Software:	Perl Client/Server

fully explained.

Follow-up imaging contributes to the long term light curves and yields information about chromatic (spectral evolution) or achromatic (jet) breaks. In addition to providing a redshift, spectroscopy can yield information about the circumburst medium, the intergalactic medium, and in some cases the emerging supernova. Finally, polarimetry is a powerful tool for probing the nature of the jet and its evolution.

SYSTEM OVERVIEW

Super-LOTIS is a fully robotic 0.6-m telescope dedicated to the search for optical counterparts of GRBs. The telescope is housed in a roll-off-roof facility at Steward Observatory's Kitt Peak site. From 1999 to 2003 Super-LOTIS was configured with a prime focus imager in order to provide better coverage of the large Burst and Transient Source Experiment (BATSE) error boxes. Selected results from that system and its predecessor, LOTIS, are included in Park et al. [2], Williams et al. [3], Schaefer et al. [4], Park et al. [5], Hurley et al. [6], Castro Cerón et al. [7], and Blake et al. [8].

The upgraded f/9 Cassegrain system uses a commercial Spectral Instruments 800 Series CCD camera equipped with a thinned 2048 × 2048 pixel E2V detector. The pixel scale of 0.5''/pixel is well matched to the image quality of the optical design and the typical site seeing. The 17' × 17' field-of-view provides full coverage of the Swift BAT error boxes. The system is linked to the GCN network and can slew at a rapid rate of approximately 8°/s which allows the telescope to begin imaging any part of the sky within 25 s of receiving a GCN trigger. Depending on the observing conditions, the system can often achieve a limiting magnitude of approximately R = 17.5 in a single 10 s exposure and R = 18.5 in a single 60 s exposure. When not observing GRBs, the system performs ancillary observing programs including nightly multi-band observations of supernovae and searches for novae in M31 and M33.

The Super-LOTIS website, <http://slotis.kpno.noao.edu/LOTIS/index.php>, provides additional details, status information, and up-to-date results. The characteristics of the system are provided in Table 1.

RECENT RESULTS

Table 2 provides a list of Swift era observations obtained by our group which resulted in GCN Circulars¹. The table is not a complete log since some of our observations did not result in GCN Circulars. The upper section of Table 2 lists events that were observed by Super-LOTIS and the lower section includes observations using other Steward Observatory facilities.

Super-LOTIS has provided the earliest *filtered* observations of all eleven bursts that the system responded to promptly. Several of those observations resulted in detections but even the early-deep upper limits provide scientifically interesting constraints. For events that were not observed promptly, either because of timing, position, weather or a delayed trigger, deeper detections or limits were achieved through co-addition of many individual frames.

Since the Swift UVOT is equipped with only blue filters the Super-LOTIS R- & I-band data complement the Swift UVOT data. The color information can provide crucial clues about the burst environment and early indications of the redshift. In addition, the Super-LOTIS observations occasionally cover gaps in the UVOT coverage which result from pointing or slewing restrictions or periods of Earth blockage. Optical observations are critical during those gaps since flares or breaks in the light curve could occur during them.

FUTURE PLANS

We plan to continue to operate Super-LOTIS as long as funding permits while at the same time expanding our use of other Steward Observatory telescopes for GRB afterglow observations. Toward this end, we have started the process of automating the 1.6-m Kuiper telescope. The Super-LOTIS operations software was written to be easily ported to the other Steward telescopes. We successfully demonstrated queue mode operation of the Kuiper telescope in October 2007. We are currently assessing the hardware modifications required to remotely control focus, mirror covers, and the dome slit. We anticipate that robotic or human assisted automated operation will be available before the end of 2008.

The twin 8.4-m Large Binocular Telescope (LBT) will begin regular science observing in February 2008. The red and blue channel prime focus cameras for the LBT can detect very faint sources and therefore we plan to use them to obtain very late images to search for supernova bumps, breaks in the light curve, and host galaxies.

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¹ The LBT data were obtained by P. Garnavich and X. Dai as part of the LBT Science Demonstration Time, see Dai et al. [9]

TABLE 2. Recent observations resulting in GCN circulars.

UT Date	Response Time	Exp. (s)	R Magnitude	GCN Circ.
071025	314.8 s (95.3 s)	10 × 60 (10)	17.97 ± 0.17 (> 17.3)	6995
071011	40.4 s	10	> 16.9	6887
071010b	13.6 h	59 × 60	> 20.4	6893
070612a	25.1 h	6 × 60	17.73 ± 0.4	6535
070610	2.5 d	60 × 60	> 20.9	6536
070419a	456 s (102 s)	60 (10)	18.49 ± 0.2 (> 17.7)	6328
061126	35 s	10	12.9 ± 0.2	5869
061102b	38 s	5 × 10	> 19.8	5780
061009	3.1 h	14 × 60	> 20.2	5742
060923	41.1 s	10	> 16.6	5588
060515	1745 s	8 × 60	> 18.1	5136
060510b	1877 s	60	> 18.6	5100
060502	1284 s (33 s)	60	> 17.9	5049
060501	1.25 h	60	> 18.6	5045
060210	94.5 s (55.1 s)	5 × 10 (10)	18.25 ± 0.29 (> 17.5)	4730
060206	4.2 h	20 × 60	17.87 ± 0.12	4699
060110	38.0 s	10	> 16.0	4469
051111	35.9 s	10	13.2 ± 0.1	4252
051109b	56.0 s	10	> 17.0	4225
051109a	43.0 s	10	15.27 ± 0.13	4218
050525	6.0 h	20 × 30	> 17.5	3485
050421	3.8 h (8.0 h)	30 × 30	> 17.5 (20.0)	3311
071025	28 m	150	18.7 ± 0.1	7011 ¹
070419a	30.8 d	15 × 200	25.71 ± 0.13	6486 ²
070419a	20.8 d	25 × 200	25.29 ± 0.5	6486 ²
070419a	27 m	60	19.12 ± 0.09	6341 ¹
070125	26.8 d	10 × 200	26.3 ± 0.3	6165 ²
060512	6.6 h	5 × 300	20.14 ± 0.16	5127 ¹
060121	5.6 h	6 × 300	23.79 ± 0.19	4558 ³
051221b	6.5 h	11 × 300	> 23.0	4420 ¹
050408	12.0 h	11 × 120	21.9 ± 0.1	3258 ¹
041217	19.5 h	2 × 300	> 21.0	2857 ³

¹ 1.6-m Kuiper ² 8.4-m LBT ³ 2.3-m Bok

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